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The strawberry leaf-roller

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Ames, Iowa, April, 1918 Bulletin No. 179 (Abridged)

IOWA AGRICULTURAL EXPERIMENT STATION

C. F. CURTISS, DIRECTOR

ENTOMOLOGY SECTION

THE STRAWBERRY LEAF-ROLLER

(*Ancylis comptana* Fröhl)

By R. L. Webster

Probably the most common strawberry insect in Iowa is the strawberry leaf-roller. Other insects are often seen on strawberry plants but usually only locally. Because several generations occur during a season, this insect soon becomes abundant in a strawberry bed, thus accounting for its common occurrence.

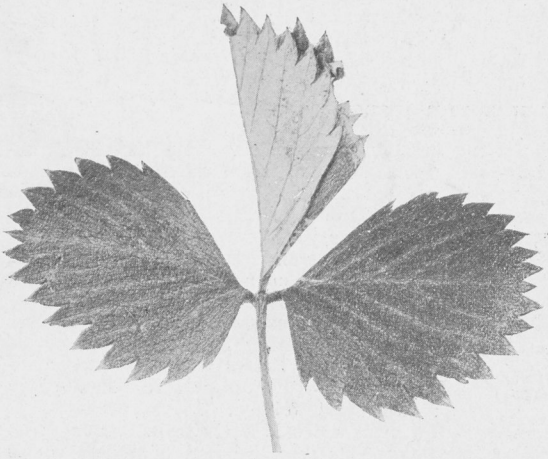

Fig. 1. Rolled strawberry leaf

Severe losses caused by this leaf-roller are frequently reported. Several years ago in certain localities in Scott county strawberry growing was practically abandoned because of this insect. One grower at Des Moines, who raises about seven acres of strawberries, recently states that his loss in 1916 due to this insect amounted to at least a thousand dollars. In the year previous his crop had brought him $1,700, but because of the leaf-roller injury in the spring of 1916, this was reduced to about $700.

APPEARANCE OF THE INJURY

In cases of severe injury, strawberry foliage becomes so dried and brown that it looks as if it had been scorched by fire. Lack of rain at the time of the injury greatly increases this appearance.

The actual damage is by the small caterpillars feeding on the leaf tissue. The whole tissue is not taken but the epidermis is eaten away so that the remainder of the leaf dries. Silken threads are spun by the leaf-roller close to the surface of the leaf. In fact, often these silken strands are the sole support for the insect when it first begins feeding. Usually the upper leaf surface is attacked but the leaf-roller works on either the upper or lower surface. As a rule an infested leaf is folded over at the mid-rib. Where the insects are abundant, however, leaves are often tied together in an indiscriminate fashion.

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THE INSECT

The insect responsible for this damage is a slender, active caterpillar, about half an inch long, and greenish or brownish in color. (See fig. 2.) There are fine hairs (setæ) on the body, but these are so small that the insect appears naked when viewed without a lens. In the fall the caterpillars are brownish in appearance, but at other times pale greenish.

Fig. 2. The leaf roller. Enlarged 6 times. (Drawing by Webster)

When full grown these caterpillars pass through the intermediate stage (see fig. 3.) Then the insect is inactive and does not feed. From this pupa emerges the moth (see fig. 4).

The adult insect, this tiny moth, is only two-fifths inch across the outstretched wings. The front wings are reddish brown, streaked with white lines; the hind wings are smoky brown.

Fig. 3. Pupa of leaf roller. Enlarged 8 times (Drawing by Ellis)

WHEN THE INSECTS APPEAR

Observations in Iowa during the last four years have established definitely the fact that this leaf-roller spends the winter in the strawberry beds as a nearly full grown caterpillar. These overwintering leaf-rollers feed to some extent very early in spring but soon mature and transform to the intermediate pupa stage and later to the adult moths. These moths deposit eggs and a new generation of leaf-rollers appears in late May and during June. This brood of leaf-rollers frequently becomes very abundant and often causes severe damage to strawberry foliage.

Fig. 4. The moth. Enlarged 4 times. (Drawing by Werner)

After these leaf-rollers are full grown, which is likely to be late in June, a new brood of leaf-rollers appears. This second brood of rollers comes on during July, and these are likely to cause damage late in that month.

Again in August the leaf-roller appears for the third generation. These third brood rollers do not usually come on before the middle of the month and young rollers are likely to be common in late August and during September and October. These third brood leaf-rollers spend the winter in strawberry foliage in the beds.

The most important facts from a study of the life history of an insect of this kind are those bearing on the practical treatment for its control. To be effective an arsenical poison must be applied early in the game, that is, before the leaf-roller has folded or rolled the foliage. After this is done spraying is ineffective, since the insect feeds within the folded leaf.

CONTROL MEASURES

There are two measures that every strawberry grower should take whenever trouble with this leaf-roller begins. By observing the foliage one may determine when damage is likely to occur and often forstall this. These measures are: Mowing off strawberry foliage after the crop is off and spraying with some arsenical poison.

ARSENICAL SPRAYING

The first chance to do effective spraying is early in May. Any arsenical spraying of strawberries, however, should be made previous to the blossoming, since application while the plants are in bloom would be likely to poison bees.

Spraying at this time, that is, about the time the eggs are deposited, is essential in order to place the poison on foliage before the eggs hatch and also before strawberries come into full blossom. Besides controlling the leaf-rollers, spraying immediately before blossoming controls the early strawberry slug, as indicated in bulletin 162 of this experiment station.

Lead arsenate paste was given a trial in the strawberry beds of Archie Greenfield, a grower near Fort Des Moines. Unfortunately heavy rains followed the application, washed this off, and little benefit was obtained. Mr. Greenfield sprayed the plants first May 15, 1917, using 3 pounds of the paste in 50 gallons of water. Eggs were common on foliage then, but none had hatched. The variety concerned was Senator Dunlap. The field was visited May 22 and June 1. Fearing that the lead arsenate would be entirely washed off Mr. Greenfield sprayed again about 10 days after the first application. However, by June 16 the rollers were common and it was evident that little benefit had been obtained.

There is no question that lead arsenate would have been effective had it remained on the foliage. According to the official weather reports at Des Moines 2.63 inches of rain fell between May 15 and May 31 inclusive, and 7.29 inches between June 1 and 16, inclusive, nearly 10 inches in 30 days. There was little chance for the material to adhere to foliage. As a matter of fact, the great shortage of crop in 1917 was no doubt due to the unfavorable weather during blossoming time.

In controlling leaf-rollers in general the time of application of an arsenical poison is the most important fact to be determined. This, naturally, must be based on a thoro study of the life history of the insect.

MOWING STRAWBERRY FOLIAGE

This has frequently been suggested by writers on this insect. In observations at Ames in 1914 and 1915 the value of mowing over foliage after the berry crop had been taken off was clearly demonstrated. The mowing was done about the time larvae were mature and the rollers were checked for the rest of the season.

When dry, strawberry foliage should be raked to the ends of the rows and burned. This is especially important since pupae are killed by the burning. Otherwise moths would emerge from this and deposit eggs for a new generation of leaf-rollers.

If extreme hot weather should follow immediately after foliage is mowed over, plants might suffer considerable injury caused by drying out. However, if well mulched with straw the chances for damage are greatly minimized.

The experience of John Raester, of Davenport, a successful strawberry grower of long experience, is worthy of mention here. Mr. Raester has practically no trouble with this strawberry insect, usually very common in the vicinity of Davenport.

New plants set out in the fall are given a thoro spraying with lead arsenate before the rollers appear. Since the insects are especially fond of new plants, this measure is highly advisable. The older beds are mowed over as soon as the crop is off and the foliage raked up and burned. This effectively disposes of any leaf-rollers or their pupae within the leaves. The new crowns are then sprayed with lead arsenate, which poisons any newly hatching rollers of the second brood.

This is done about the last of June. A complete study of the life history of the insect indicates that the last of June or first of July is the proper time for the application of an arsenical spray to strawberry foliage. The eggs are being deposited on the leaves early in July and any spraying, to be effective, should be applied before these eggs hatch.

Arsenical spraying in late summer should be made during August. In an ordinary season late in August would be timely but it should not be delayed until September. If the adult moths are common at any time this is an indication that it is time to spray for the leaf-rollers.

MEASURES ADVISED

The use of lead arsenate paste, 3 pounds in 50 gallons of water, is recommended for the leaf-rollers. If the powder is used, half that amount only is necessary. There are three times during the season when this material may effectively be used on strawberry plants. First, when the first blossoms appear, (about May 1); second, after the crop is off (about July 1); third, late in August. The May application is the most important.

Mowing over strawberry foliage immediately after the crop is off is no less valuable a measure. The leaves should be raked up and burned as soon as dry.

November, 1918 Bulletin No. 179

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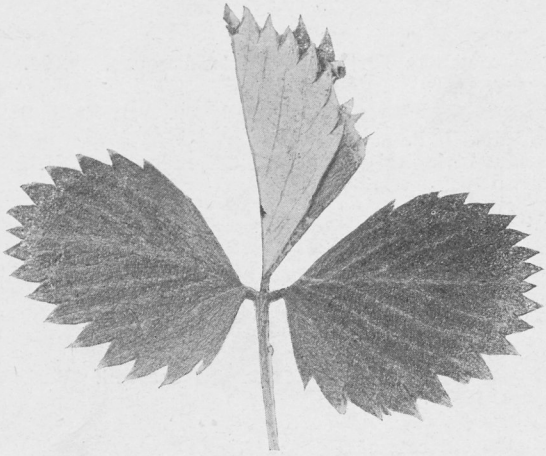

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Entomology Section

Ames, Iowa

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Fig. 1. Rolled Strawberry Leaf.

Severe losses caused by the leaf-roller are frequently reported. Several years ago in certain localities in Scott county strawberry growing was practically abandoned because of it. One grower at Des Moines, who raises about seven acres of strawberries, recently stated that his loss in 1916 due to this insect amounted to at least a thousand dollars. In the year previous his crop had brought him $1,700, but because of the leaf-roller injury in the spring of 1916, this was reduced to about $700.

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The insect responsible for this damage is a slender, active caterpillar, about half an inch long, and greenish or brownish in color, according to the season. (See fig. 2.) There are fine hairs (setae) on the body, but these are so small that the insects appear naked when viewed without a lens. In the fall the caterpillars are brownish in appearance, but at other times pale greenish.

Fig. 2. The leaf roller. Enlarged 6 times. (Drawing by Webster)

When full grown these caterpillars pass thru the intermediate pupa stage (see fig. 3). At that time the insect is inactive and does not feed. From this pupa emerges the moth (see fig. 4).

The adult insect, this tiny moth, is only two-fifths of an inch across the outstretched wings. The front wings are reddish brown, streaked with white lines; the hind wings are smoky brown.

Fig. 3. Pupa of leaf roller. Enlarged 8 times. (Drawing by Ellis)

WHEN THE INSECTS APPEAR

Observations in Iowa during the last four years have established the fact that this leaf-roller spends the winter in the strawberry beds as a nearly full grown caterpillar. These overwintering leaf-rollers feed to some extent very early in spring but soon mature and transform to the intermediate pupa stage and later to the adult moths. These moths deposit eggs and a new generation of leaf-rollers appears late in May and during June. This brood of leaf-rollers frequently becomes very abundant and often causes severe damage to strawberry foliage.

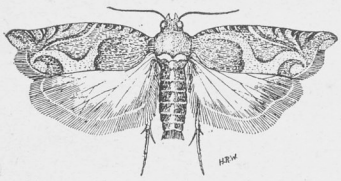

Fig. 4. The moth. Enlarged 4 times. (Drawing by Werner)

After these leaf-rollers are full grown, which is likely to be late in June, a new brood of leaf-rollers appears. This second brood of rollers comes on during July and is likely to cause damage late in that month.

Again in August the leaf-roller appears for the third generation. These third brood rollers do not usually come on before the middle of the month and young rollers are likely to be common in late August and during September and October. The third brood leaf-rollers spend the winter in strawberry foliage in the beds.

The most important facts gained from a study of the life history of an insect of this kind are those bearing on the practical treatment for its control. To be effective an arsenical poison must be applied early in the game, that is, before the leaf-roller has folded or rolled the foliage. After this occurs spraying is ineffective, since the insect feeds within the folded leaf.

CONTROL MEASURES

There are two measures that every strawberry grower should take whenever trouble with the leaf-roller begins. By observing the foliage one may determine when damage is likely to occur and often forestall this. These measures are mowing off strawberry foliage after the crop is off and spraying with some arsenical poison.

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The first chance to do effective spraying is early in May. Any arsenical spraying of strawberries, however, should be made previous to the blossoming, since applications while the plants are in bloom would be likely to poison bees.

Spraying at this time, which is the time the eggs are deposited, is essential in order to place the poison on foliage before the eggs hatch and also before the strawberries come into full blossom. Besides controlling the leaf-rollers, spraying immediately before blossoming controls the early strawberry slug, as indicated in Bulletin 162 of the Iowa Agricultural Experiment Station.

Lead arsenate paste was given a trial at the strawberry beds of Archie Greenfield, a grower near Fort Des Moines. Unfortunately heavy rains followed the application and washed off the paste and little benefit was obtained. Mr. Greenfield sprayed the plants first May 15, 1917, using 3 pounds of the paste in 50 gallons of water. Eggs were common on foliage then, but none had hatched. The variety was Senator Dunlap. The field was visited May 22 and June 1. Fearing that the lead arsenate would be entirely washed off Mr. Greenfield sprayed again about 10 days after the first application. However, by June 16 the rollers were common and it was evident that little benefit had been obtained.

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In controlling leaf-rollers the time of application of an arsenical poison is the most important fact to be determined. This, naturally, must be based on a thoro study of the life history of the insect. In this bulletin is given a detailed account of the life history, on which the recommendations for control are mainly based.

MOWING STRAWBERRY FOLIAGE

It has frequently been suggested by writers on this insect that strawberry foliage be mowed after the berry crop has been taken off. In observations at Ames in 1914 and 1915 the value of this method was clearly demonstrated. The mowing was done about the time larvae were mature and the rollers were checked for the rest of the season.

When dry, strawberry foliage should be raked to the ends of the rows and burned. This is especially important in order that the pupae may be destroyed. Otherwise moths would emerge and deposit eggs for a new generation of leaf rollers.

If extreme hot weather should follow immediately after foliage is mowed over, the plants might suffer considerable injury caused by drying out. However, if they are well mulched with straw the chances for damage are greatly minimized.

The method used by John Racster of Davenport, a successful strawberry grower of long experience, is worthy of mention here. Mr. Racster has practically no trouble with this strawberry insect, usually very common in the vicinity of Davenport.

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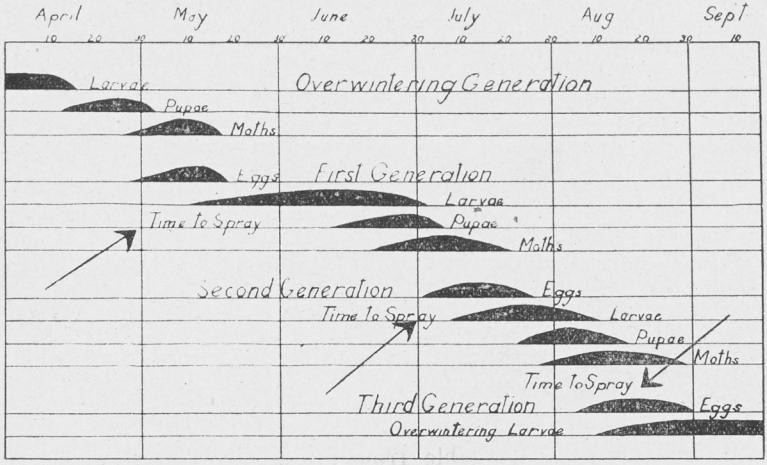

Fig. 5. Diagram of life history, showing proper times during season for spraying

especially fond of new plants, this measure is highly advisable. The older beds are mowed over as soon as the crop is off and the foliage raked up and burned. This effectively disposes of any leaf-rollers or their pupae within the leaves. The new crowns are then sprayed with lead arsenate, in order to poison any newly hatching rollers of the second brood.

This is done about the last of June. Reference to the diagram of the life history (fig. 5) indicates that the last of June or first of July is the proper time for the application of an arsenical spray to strawberry foliage. The eggs are being deposited on the leaves early in July and any spraying, to be effective, should be applied before these eggs hatch.

Arsenical spraying in late summer should be made during August. In an ordinary season late August would be timely but the spraying should not be delayed until September. If the adult moths are common at any time this is an indication that it is time to spray for the leaf-rollers.

MEASURES ADVISED

The use of lead arsenate paste, 3 pounds in 50 gallons of water, is recommended for the leaf-rollers. If the powder is used only half that amount is necessary. There are three times during the season when this material may effectively be used on strawberry plants. First, when the earliest blossoms appear, (about May 1); second, after the crop is off (about July 1); third, late in August. The May application is the most important.

Mowing over strawberry foliage immediately after the crop is off is no less valuable a measure. The leaves should be raked up and burned as soon as dry.

DISTRIBUTION

This leaf-roller occurs in Iowa wherever strawberries are grown. Nursery inspectors working under the direction of the State Entomologist report the insect from practically all parts of the state. It is probably the most common insect occurring on strawberries.

States of the Mississippi Valley apparently have had the most trouble with this insect for it has been recorded in the literature as occurring in practically every state between the Appalachian and the Rocky Mountains. Outside this area, it is less common.

In response to letters of inquiry regarding the distribution of this leaf roller, sent to entomologists all over the country many interesting facts were learned.

No records were available from Maine or New Hampshire, H. T. Fernald wrote that the insect is generally distributed in Massachusetts. W. E. Britton made a similar statement for

Connecticut. Few reports of the insect have been made in New York state but E. P. Felt wrote that the insect appears to be widely distributed, fairly common, altho not enough to be ranked as abundant. In New Jersey letters from T. J. Headlee and H. B. Weiss stated that the insect occurs generally over the state altho it is more abundant in the Southern section where the soil is better adapted for the growing of strawberries. C. O. Houghton wrote that the leaf-roller is generally distributed in Delaware but is more common in the south portion.

In Maryland E. N. Cory stated that he had never seen the insect in sufficient numbers to be termed a pest. Fred E. Brooks observed the insect only at French Creek in West Virginia and there but rarely. Loren B. Smith has captured a few adult moths in eastern Virginia. No records were available from North Carolina, South Carolina, Georgia, Florida, Alabama or Tennessee. H. Garman studied this leaf-roller in Kentucky and wrote that it was common there.

In Northern Ohio, W. H. Goodwin has seen the insect frequently but never in large numbers. L. Caesar, provincial Entomologist in Ontario, stated that the leaf-roller occurs fairly widely in Ontario altho it is not regarded as a strawberry pest. R. H. Pettit wrote that it is common in Michigan wherever strawberries are grown. Similar conditions occur in Indiana, according to James Troop.

Mr. Forbes has frequently written of this leaf-roller in the reports of the State Entomologist of Illinois, where it has often been referred to as destructive. In Wisconsin, S. B. Fracker has seen this insect commonly in the southern portion. A. G. Ruggles stated that it is only fairly common in Minnesota especially in the vicinity of the Twin Cities. In Nebraska according to Lawrence Bruner and M. H. Swenk, the leaf-roller is often abundant, especially in the eastern portion along the Missouri river, altho it also occurs in western Nebraska. Conditions are similar in Kansas, according to George A. Dean, who stated that the insect is kept well under control by strawberry growers in eastern Kansas.

In Missouri this leaf-roller often become abundant as is evidenced by the published records of Riley and Stedman. O. W. Rosewall stated that it was common in Baton Rouge, Louisiana, and also in the parish of Tangipahoa, which is the center of the strawberry growing section of the state. George G. Becker wrote that a strawberry leaf-roller, which he thinks likely to be this species, is common in the large strawberry district of Arkansas.

No records were available from Oklahoma, Texas or Arizona. C. P. Gillette wrote that the leaf-roller has been a rather serious pest in the Arkansas Valley of Colorado. It has also been found

in northern Colorado and on the western slope of the Grand Valley. R. A. Cooley wrote that the insect occurred on both sides of the Rocky Mountains in Montana.

Altho the insect has been recorded from California it seems to have caused no special notice there. C. V. Piper found it abundant in Washington. A. L. Melander wrote that the leaf-roller occurs in both eastern and western Washington, generally wherever strawberries are grown.

FOOD PLANTS

Dr. C. H. Fernald, (1882) listed the following as the European food plants of *Ancylis comptana, Potentilla opaca, verna* and *cinerea, Dryas octopetela, Poterium sanguisorba, Thymus serpyllum, Teucrium.* In North America the insect is apparently restricted to a very few plants. Besides the strawberry its only other known food plants, according to the literature, are the blackberry and raspberry.

In the Iowa work the insect was not observed on the blackberry and raspberry in the field, altho when placed on blackberry foliage in the insectary larvae fed readily. That it frequently occurs on the blackberry and raspberry is indicated in letters to the writer from other entomologists. E. N. Corey wrote that the insect caused slight damage recently to red raspberry in Maryland. Fred E. Brooks also observed it on raspberries in West Virginia.

PAST HISTORY AND DESTRUCTIVENESS.

As early as 1866 this insect was observed to cause severe damage to strawberries at Valparaiso, in northern Indiana, according to Dr. C. V. Riley (1869). Riley also recorded that the insect caused severe damage in northern Illinois in 1868.

Osborn (1880) first mentioned this leaf-roller as causing damage in Iowa in 1879. In the vicinity of Muscatine damage occurred as early as 1880, according to Miss Walton (1881). Forbes (1884) has reported considerable damage in Illinois. John B. Smith (1901), (1909) reported severe damage in New Jersey. Garman (1890) in Kentucky and Pettit (1904) in Michigan reported damage. Stedman (1901) recorded severe damage to strawberries in Missouri, Swenk (1908) in Nebraska and Gillette (1900) in the strawberry districts in Colorado. Other writers have frequently mentioned the insect as destructive.

CLASSIFICATION

According to specialists on this group of moths the strawberry leaf-roller is common in Europe. It was first described by Frölich (1828) who called the insect *Tortrix comptana.* Walker

(1863) described a moth which he named *Grapholita conflexana*, but this appears to be a synonym of the species described by Frölich. Walsh and Riley (1869) called this insect a new species when they first began writing on it and gave it the name of *Anchylopera fragariae*. This is now considered a synonym. The species is now placed in the genus *Ancylis* and the synonym generally accepted is as follows:

Ancylis comptana Frölich 1828
conflexana Walker 1863
fragariae Walsh and Riley 1869

Common Name. This particular species, of all the leaf-rollers affecting strawberries, is by far the most common in this state and is preeminently the "strawberry leaf-roller." This common name has been adopted by the American Association of Economic Entomologists and is used herein.

LIFE HISTORY

HIBERNATION

Many contradictory statements have been made as to the manner in which this leaf-roller spends the winter. Riley (1869) stated that the insect hibernated as the pupa. Forbes (1884) said that a considerable number of the moths wintered over, appearing on the wing early in spring. Stedman (1901) made the definite statement that the insect wintered as larvae in Missouri. M. H. Swenk (1908) said that the winter is spent as pupae and J. B. Smith (1909) indicated that this was the case in New Jersey. According to C. A. Hart (1911) it was concluded that the larvae hibernated in central Illinois.

In central Iowa the winter is spent at larvae, according to observations made at Ames during several years. Only larvae were found at Ames October 3, 1913, October 19 and 22, 1914 and at Des Moines October 14, 1916. A few larvae collected in the fall of 1913 wintered over in dried strawberry foliage in the insectary. April 13, 1914, four larvae were present, no pupae, but pupation occurred late in April.

At Ames on April 13, 1914, larvae and pupae were found in about equal numbers encased in the old dried leaves. Most of the pupae were light brown, evidently only recently pupated. April 16, three days later, only pupae were found here.

THE GENERATIONS

Riley (1869) stated that two generations occurred in Missouri, but Stedman (1901)indicated three. Garman (1890) found that three generations occurred in Kentucky. In the

economic literature most writers have followed the old statement of Riley. M. H. Swenk (1908) recorded three generations in Nebraska and C. A. Hart (1911) four in central Illinois.

In central Iowa the data show that normally three full generations occur. In the summer of 1915, which was exceptionally cool, indications are that only two generations appeared. Fig. 5 gives a diagram of the life history, based for the most part on field observations.

The writer (1918) has previously made the statement that a partial fourth generation occurred in central Iowa. A more critical review of the data, especially in correlation with weather conditions of the years during which observations were made, shows that such statement was hardly warranted. The evidence of a partial fourth generation is given later on in this article.

During the latter part of the summer larvae may be commonly found. In 76 field observations, March 26 to October 22, larvae are recorded in 59 instances. Therefore generalizations become rather difficult, especially when the data cover several years of such varying weather conditions as the years 1914 to 1917 in Iowa. A summary of all field notes is given in table I. The various stages of the insect are indicated as being rare, common or abundant in each instance.

TABLE I—SUMMARY OF FIELD NOTES, 1914-1917.

Date	Locality	Eggs	Larvae	Pupae	Moths	Observer
March 26, 1915	Ames		Rare			RLW
April 13, 1914	Ames		Common	Common		RLW
April 16, 1914	Ames			Common		RLW
April 18, 1917	Des Moines			Common		RLW
April 21, 1914	Ames			Common		RLW
April 28, 1914	Ames	Rare		Common	Rare	RLW
May 4, 1914	Ames	Rare		Rare	Abundant	RLW
May 8, 1917	Des Moines	Rare[1]		Rare	Rare	RLW
May 9, 1914	Ames	Abundant			Rare	RLW
May 15, 1917	Des Moines	Common			Common	RLW
May 16, 1914	Ames	Common			Rare	RLW
May 19, 1917	Davenport	Common				RLW
May 25, 1914	Ames		Common[2]			RLW
June 8, 1914	Ames		Abundant[2]	Rare		RLW
June 9, 1914	Ames		Common	Common		RLW
June 9, 1915	Ames		Common			WOE
June 11, 1915	Ames		Rare			WOE
June 14, 1914	Ames		Common			WOE
June 15, 1914	Ames	Rare	Common	[3]	Rare	WOE
June 15, 1917	Ottumwa		Common			RLW
June 16, 1917	Des Moines		Common			RLW
June 16, 1917	Davenport		Common			JLH
June 17, 1914	Ames		Common	Common		WOE
June 18, 1917	Davenport		Common			JLH
June 19, 1914	Ames		Rare	Abundant		WOE
June 24, 1914	Ames	Rare	Rare	Abundant[4]		WOE
June 25, 1917	Davenport		Common	Rare		JLH
June 28, 1915	Ames		Rare	Common	Rare	WOE
June 29, 1917	Davenport		Common	Common		JLH
June 30, 1914	Ames	Abundant			Abundant	WOE
July 2, 1917	Davenport			Abundant		JLH

TABLE I—SUMMARY OF FIELD NOTES, 1914 1917—CONTINUED.

Date	Locality	Eggs	Larvae	Pupae	Moths	Observer
July 3, 1917	Davenport		Rare	Common		JLH
July 7, 1914	Ames	Rare	Common	Rare		WOE
July 11, 1917	Davenport	Rare		Common	Rare	JLH
July 13, 1916	Nevada		Rare	Rare	Common	JLH
July 13, 1917	Davenport	Common	Rare	Rare	Abundant	JLH
July 14, 1916	Ames		Rare			HRW
July 14, 1916	Nevada		Rare	Rare	Common	JLH
July 16, 1915	Ames	Rare	Rare		Rare	WOE
July 18, 1916	Des Moines		Abundant		Common	JLH
July 19, 1915	Ames	Rare	Rare		Rare	WOE
July 22, 1914	Ames		Abundant	Common		WOE
July 24, 1914	Ames		Abundant	Common		WOE
July 24, 1916	Ames	Rare[5]				JLH
July 24, 1916	Nevada		Common			JLH
July 25, 1917	Davenport		Common			JLH
July 27, 1914	Ames		Common	Common		WOE
July 29, 1914	Ames		Abundant	Common		WOE
July 29, 1916	Des Moines		Common	Rare		JLH
August 3, 1914	Ames		Common	Abundant		WOE
August 3, 1916	Cedar Falls		Abundant	Rare		CAR
August 3, 1916	Omaha, N.	Rare	Common	Abundant	Rare	RLW
August 4, 1915	Ames		Common			WOE
August 5, 1914	Ames	Common	Common	Common	Rare	WOE
August 6, 1917	Davenport		Abundant			JLH
August 10, 1914	Ames		Rare		Rare	WOE
August 12, 1914	Ames	Abundant	Common	Rare	Rare	WOE
August 13, 1914	Ames	Common	Rare		Abundant	WOE
August 13, 1915	Ames		Common			WOE
August 20, 1914	Ames	Rare	Abundant		Rare	WOE
August 21, 1914	Ames	Rare	Abundant		Rare	WOE
August 22, 1917	Davenport		Rare	Abundant	Rare	JLH
August 28, 1914	Ames		Common			WOE
August 28, 1917	Davenport	Common	Rare[6]	Rare	Abundant	JLH
Sept'ber 4, 1914	Ames		Common			WOE
Sept'ber 9, 1916	Des Moines		Abundant	Rare	Rare[7]	RLW
Sept'ber 10, 1916	Oskaloosa		Common			HN
Sept'ber 12, 1914	Ames		Common	Rare		WOE
Sept'ber 17, 1914	Ames		Common			RLW
Sept'ber 23, 1914	Ames		Common			RLW
Sept'ber 29, 1913	Ames		Abundant			RLW
October 3, 1913	Ames		Abundant			RLW
October 14, 1916	Des Moines		Common			RLW
October 19, 1914	Ames		Common			RLW
October 22, 1914	Ames		Common			RLW

[1] One egg found on this date.
[2] These were young larvae..
[3] No pupae found, altho moths recorded.
[4] Empty pupal cases found.
[5] "Hatched eggs."
[6] Newly hatched larvae.
[7] One moth seen.

OVERWINTERING GENERATION.

To avoid confusion it may be well to define terms, with reference to the different broods and generations. In this article all those larvae that hibernate are considered as belonging to the "overwintering generation." Pupae and moths from these larvae, belong to the overwintering generation. The first generation, then, begins with the eggs deposited in May and June.

Overwintering larvae are practically mature. Evidently these do little or no feeding in early spring, since practically all were found in dried foliage in the field. In many cases overwintering larvae pupated in the insectary in spring without feeding.

At Des Moines, April 18, 1917, only pupae were found, and these in abundance. One was empty, indicating the emergence of a moth. The following day a single moth emerged in the insectary at Ames, from a pupa collected at Des Moines April 18.

In 1914 moths began to emerge in the insectary on April 15. In this case the larva had been collected the fall previous and carried thru the winter in the insectary. Evidently moths appear normally during the latter half of April. Records of the appearance of adult moths during the season are given in table VIII.

FIRST GENERATION

This begins with eggs deposited by moths from overwintering larvae. The earliest date eggs of this generation have been recorded outside is April 28, 1914 at Ames. They were abundant there May 9 and 16, but none had yet hatched. At Des Moines May 15 and at Davenport May 17, 1917, eggs were common, altho none had then hatched.

There is a close correlation between the time in the spring when these eggs appear and the time of strawberry blossoming. The moths begin to deposit their eggs at about the same time that the first blossoms appear on strawberry plants. The importance of this fact is shown in the discussion of control measures, because the blossoming of strawberry plants indicates when to spray for the leaf-roller.

Young larvae were common May 25, 1914 at Ames; the earliest date. In the insectary eggs hatched early in May, 1914. However, the larvae do not become sufficiently abundant to cause damage until June. Pupae are recorded as early as June 8 and 9, 1914, at Ames, but were not especially common. The observation on June 9 indicated a field where conditions were considerably in advance of other fields.

W. O. Ellis observed moths of this generation June 15, 1914, but they were not common. The notes indicate that all stages of larvae were abundant and causing much rolling of foliage. Moths are recorded as common or abundant late in June and during the fore part of July. At Ames they were seen July 19, 1915, indicating probably the last of this brood of moths.

SECOND GENERATION

June 24 is the earliest field record for second brood eggs. W. O. Ellis found a very few of these at Ames in 1914. Eggs

Fig. 6. Cast pupal skins.

were abundant June 30 at the same place. Conditions in 1914, however, were in advance of normal, and in that year all the months, except February, April and December were warmer than usual. At Davenport eggs were rare July 11, but common July 13, 1917, according to J. L. Horsfall.

Second brood larvae were abundant July 7, 1914, at Ames. Ellis recorded young larvae common then, but this date is early for second brood larvae. July 15, 1915 young larvae were found at Ames only rarely, but this was probably due to the exceptionally cool weather of the summer of 1915. At Des Moines July 18, 1916, larvae of all stages were observed, according to notes of J. L. Horsfall and C. A. Reese. From this time on during the season the larvae may be found practically at any time. In fact, the notes indicate that larvae were observed, with but a single exception, on every field observation from July 13 until October 22. The exception was in a small patch where only occasional records were made and where the insect had not been common.

In 1914 Ellis found pupae as early as July 22 at Ames. Altho pupae were common late in July, 1914, Ellis estimated that on July 29 he found three larvae to every pupa. In 1916 Horsfall observed pupae of this generation July 29 at Des Moines. At this time larvae were extremely common and larvae outnumbered pupae five to one. August 3, in 1914, the pupae outnumbered larvae at Ames.

The earliest record for second generation moths is August 3 1916 at Omaha, Nebraska, by the writer. An occasional moth was observed in a badly infested strawberry field. Pupae were most common, altho many larvae were still present. Ellis recorded second brood moths at Ames on August 5, 10, 12, 13, 20 and 21 in 1914, rare on the earlier dates, abundant on the 13th and less common later.

THIRD GENERATION

The earliest record for eggs of this generation is August 3 when a few were observed by the writer in a strawberry bed near Omaha, Nebraska, in 1916. In 1914 Ellis found eggs common at Ames August 5, 12 and 13 and more on August 20. In 1917 no eggs were observed until August 28 at Davenport, altho moths were present August 22. However, the summer of 1917 was cool, while that of 1914 was extremely warm.

August 5 is the earliest record for young larvae. W. O. Ellis observed a few newly hatched larvae at Ames on this date in 1914. They were also observed August 10, 12 and 13, but were rare. August 20 and 21, 1914, Ellis found third brood larvae abundant at Ames. August 28, 1917, at Davenport, Horsfall found a few young larvæ.

Field observations record young larvae as usually abundant during September. On the 4th small to half grown larva were common at Ames. September 9, 1916, young larvae were common at Des Moines. Rarely mature larvae or pupae were seen. Ellis observed two pupae September 12, 1914, but found none after that date. During October only larvae were observed.

EVIDENCE OF PARTIAL FOURTH GENERATION

There is some evidence that a partial fourth generation may sometimes appear, but careful scrutiny of the data shows that this is comparatively small and not important. At first it was thought that a considerable brood of larvae belonging to a fourth generation appeared in late August and in September but this seems to be a wrong interpretation of the data.

Adult moths are recorded (see table VII) in the insectary during the last 10 days of August and the first 10 days of September. These moths are likely to belong to the third generation, and originate from third brood larvae that were late in reaching maturity. Horsfall observed moths extremely abundant and depositing eggs at Davenport August 28, 1917. At first it was thought that these were fourth brood eggs, since in 1914 moths and eggs were found as early as August 5, and were common August 13. However, conditions in 1914 were advanced because of the extreme warm weather, and it is more logical to assume that the eggs observed in August, 1917, are really third brood eggs.

That moths of an additional brood do rarely appear is shown by insectary notes in 1914, when conditions during the season were much advanced. Forty-five eggs (third brood) deposited on the night of August 4, in an insectary cage, hatched August 10, 11 and 12. Eleven young larvae were removed to individual cages on strawberry foliage. Four larvae pupated in the fall, and from two of these moths emerged September 7 and 12. The other two pupae died. From this same lot of cages, however, other larvae lived thru the winter and two moths emerged April 24 and 25. From this it appears that moths of a possible fourth generation may emerge in the fall.

VARIATION IN COLOR OF LARVAE

Riley (1869) mentions a variation in color of larvae from light yellowish brown to dark olive green or brown. This varia-

tion has also been recorded by other writers. This color appears to be seasonal in its occurrence, according to our observations in Iowa. During the greater part of the season the normal color is a pale yellow-green. In September and October as the cooler weather comes on the larvae assume a dull olivaceous color. In the fall both light and dark colored larvae have been found at the same time. In spring the overwintering larvae are dark in color, but the first generation from eggs are light.

In two instances dull colored larvae were observed in late spring. At Otumwa June 15 and at Des Moines June 16, 1917, these olivaceous larvae were rather common. The weather immediately previous to this was cold and rainy, resulting in a great shortage in the strawberry crop. Such conditions, especially those of temperature, are likely to occur in the fall, and it seems probable that low temperature is in part at least responsible for the difference in coloration.

WHAT BROODS CAUSE MOST DAMAGE?

All three broods of this leaf-roller may cause considerable trouble to strawberry foliage. Experience with the insect for several years under different conditions shows that severe damage may arise from any brood. The insect shows a decided tendency to attack young plants and the tender foliage of these is often much rolled up soon after the new plants are set. The second brood together with dry weather in summer frequently makes a sorry looking strawberry bed. Not only are plants greatly retarded in growth but many of them are unable to survive and die out entirely.

THE EGG

DESCRIPTION

J. M. Stedman (1901) seems to have been the first to observe the eggs and they were described by him, altho no measurements were given. J. B. Smith (1909) also described the eggs and C. A. Hart (1911) working over notes made by J. J. Davis and the writer, employed by the Illinois state entomologist in 1905 and 1906, gave a description and measurements. A detailed description is given herewith.

The egg: Oval, varying greatly, much flattened; pale yellow-green, translucent. Surface pitted with numerous slight hexagonal depressions. Length .68 mm., width .48 mm. (Average of 10 specimens deposited on foliage.)

Eggs deposited on the glass in insectary cages were quite uniform in shape; a true oval. The fine hairs on the surface of the strawberry leaf make considerable difference in the shape of the egg on a leaf.

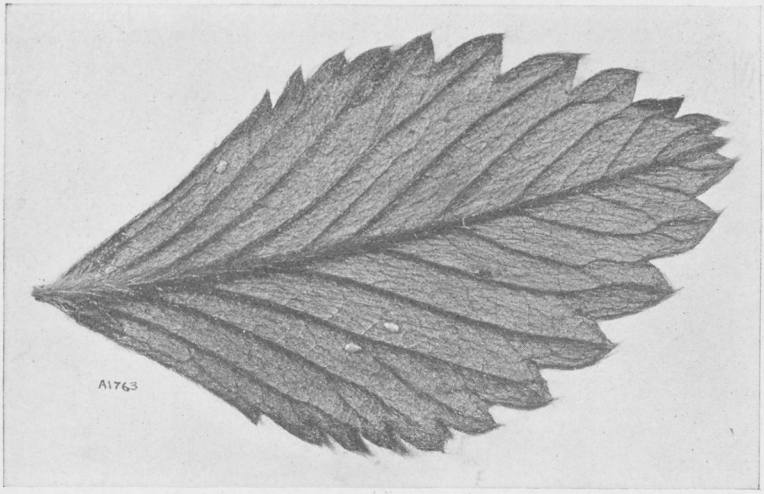

Fig. 7. Leaf-roller egg on strawberry leaf. Enlarged.

PLACE OF DEPOSITION

Stedman, Hart and J. B. Smith all state that the eggs are deposited on the under sides of the leaves. J. B. Smith said that he had never seen an egg on the upper leaf surface.

In our field observations eggs were found placed on both surfaces and even on the stems. In the insectary cages eggs were usually deposited on the upper leaf surface but were frequently placed on the inner surface of the glass chimney in which the moths were confined.

Field notes made at Ames in May, 1914, show a wide variance in the place of deposition as indicated in table II.

TABLE II—PLACE OF EGG DEPOSITION

Date of Examination	No. Leaves Examined	Eggs Found on Upper Surface	Eggs Found on Lower Surface	Eggs Found on Stems	Observer
May 4, 1914	50	0	8	0	RLW
May 9, 1914	100	3	37	1	RLW
May 16, 1914	100	45	3	0	RLW
June 30, 1914	40	4	51	0	WOE

[1]The initials refer to R. L. Webster and W. O. Ellis.

Field observations in general indicate that while eggs were placed on both surfaces on the whole the lower surface was evi-

dently preferred. The highest number of eggs found on a single strawberry leaf in the field was five, as observed by W. O. Ellis in June, 1914.

LENGTH OF THE EGG STAGE.

Considerable difference was found in the length of the egg stage in spring and in summer. In the insectary in May, 1914, according to notes by the writer, eggs hatched in 11.1 days, an average from 104 eggs. The range is given in table III.

TABLE III. LENGTH OF THE EGG STAGE—MAY, 1914

Days to hatch.	Number of eggs.
9	11
10	29
11	5
12	56
13	3
	Total 104 eggs.

Average 11.1 days.

In July and August, 1914 much less time was required, 115 eggs being hatched in 5.5 days (average) according to notes by W. O. Ellis. The range was from 3 to 8 days, as shown in table IV.

TABLE IV—LENGTH OF THE EGG STAGE: JULY—AUGUST, 1914

Days to hatch.	Number of eggs.
3	4
4	12
5	50
6	23
7	13
8	13
	Total 115 eggs.

Average 5.5 days.

Much more time was required in July and August, 1915 and an average of 8.5 days resulted in computing the data from 108 eggs. The effect of temperature is clearly evident here, since August, 1915 was the coolest August on record and July, 1915 with one exception the coolest July.

July, 1914, on the contrary, was, with one exception, the warmest July on record, so that the extremes of temperature in

a great many years have affected the records of the egg stage of this insect.

The range in July and August, 1915 was from 3 to 12 days, from the insectary notes of W. O. Ellis, as indicated in table V.

TABLE V—LENGTH OF EGG STAGE: JULY—AUGUST, 1915.

Days to hatch.	Number of eggs.
3	1
4	0
5	0
6	11
7	7
8	38
9	25
10	12
11	12
12	2
Average 8.5 days.	Total 108 eggs.

Only one accurate record is available for July, 1916, when 21 eggs hatched in 5 days.

NUMBER OF EGGS DEPOSITED BY ONE FEMALE.

So far as the writer is aware no previous record has been kept of the number of eggs deposited by a single female moth. In the insectary experiments were made at various times to determine this. Single pairs of moths were placed under large glass lantern globes which enclosed growing strawberry plants and daily records were made of all eggs deposited in the cages. A little sweetened water or honey and water was usually placed in a Syracuse watch glass in the cage as food.

The moths were usually placed in the insectary cages within a day or so after emergence. As a rule the females did not oviposit at once but it was 3 or 4 days before egg deposition occurred to any extent.

Oviposition took place during the night. The highest number of eggs deposited by one female in 24 hours was 53 on the night of August 15, 1916, according to a record by J. L. Horsfall.

The records of 35 females indicate an average of 72.9 eggs per female. This average is undoubtedly low, because some moths died soon after being placed in the cage, and consequently did not deposit a normal number of eggs.

The highest number of eggs deposited by one female was 136, according to a record by J. L. Horsfall in August, 1916. The

lowest number was 12. In this last case the moth died the seventh day after being placed in the cage. Records of the individual experiments are given in table VI.

TABLE VI—NUMBER OF EGGS DEPOSITED BY INDIVIDUAL FEMALE MOTHS.

Experiment No.	Date	No. of Eggs	Observer[1]
18	Apr., 1914	31	RLW
19	Apr. May, 1914	155 (2 females)	RLW
23	"	128	RLW
24	"	116	RLW
25	"	73	RLW
31	"	105	RLW
32	May, 1914	106	RLW
38	"	125	RLW
42	"	58	RLW
43	"	72	RLW
46	"	107	RLW
114	June, 1914	40	WOE
123	"	26	WOE
128	June-July, 1914	96	WOE
141	July, 1914	56	WOE
274	August, 1914	86	WOE
276	"	12	WOE
287	"	51	WOE
288	"	32	WOE
8	April, 1915	93	RLW
119	June-July, 1915	75	WOE
123	July, 1915	26	WOE
148	"	82	WOE
299	Aug.-Sept., 1915	69	PLE
376	July, 1916	57	JLH
406	August, 1916	51	JLH
407	"	78	JLH
416	"	77	JLH
421	"	136	JLH
422	"	58	JLH
428	"	62	JLH
429	"	67	JLH
438	"	96	JLH
451	"	52	JLH

[1]The initials refer to R. L. Webster, W. O. Ellis, P. L. Edwards and J. L. Horsfall.

THE LARVAL STAGES.

Newly hatched larvae are about 1.5 mm. long. Four larval stages were determined by W. O. Ellis in the insectary in 1914. Single newly hatched larvae were isolated in glass vials, fed on strawberry foliage, and the moults carefully observed.

Measurements of the head widths were made after each moult and recorded. From all the data accessible, head width measurements of the four stages averaged as follows: stage I, .22 mm.; stage II, .33 mm.; stage III, .59 mm.; stage IV, .85 mm.

In 16 cases accurate records of the length of the entire larval stage from egg to the pupa, were secured. These averaged 19.8 days, from larvae reared in July and August.

Some data were secured on the length in days of the several larval stages. Eighteen records for stage I showed an average of 4.5 days for this stage. 11 records for stage II, averaged 3.7 days and the same number for stage III averaged 5.3 days. 10 records for stage IV gave an average of 6 days. The data from which these results are obtained were secured by W. O. Ellis in 1914 and 1915 and by J. L. Horsfall in 1916.

Mature larvæ are fusiform, greenish-yellow or dull bronze green in color and about 10 mm. in length. The head is pale clay-yellow.

HABITS OF THE LARVAE

Newly hatched larvae begin to feed on the lower epidermis of strawberry foliage, at first eating out small areas close to the midrib or larger veins. The young leaf-rollers spin a fine web of silken threads close to the leaf surface and feed beneath this. Not until the larvae are at least half grown do they roll entire leaves. Most frequently the leaf is folded over at the midrib, as indicated in fig. 1.

THE PUPA

Pupae were always formed within the rolled foliage. Before the moths emerge the pupae wriggle out so that the fore portion is exposed. Empty pupae are frequently observed protruding from a dried leaf, as in fig. 8.

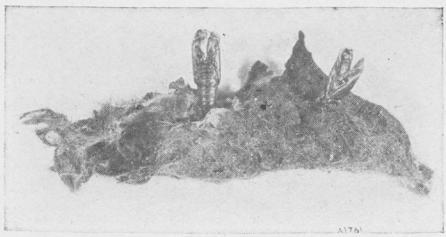

Fig. 9. Empty pupae on leaf.

Dr. Forbes (1884) gave the following description of the pupa:

The pupa is slender-ovate, pale brown, 5 mm. long by 1.4 mmi wide. The abdomen is smooth beneath, and armed at the posterior extremity with several slender hairs, which are abruptly hooked at tip. Above, each abdominal segment bears two transverse rows of stout, recurved, spinous tubercles, one near the anterior, and one near the posterior margin of each segment excepting the last, which bears three rows. The anterior row on each segment contains fewer but larger spines

than the posterior, the former becoming larger from before backwards, and the latter smaller.

LENGTH OF PUPA STAGE

Less time is spent in the pupa stage in summer than in spring. From meagre data the length of this stage in April and May was found to be from 14 to 18 days.

In the summer months an average of 6.6 days was spent as pupae. This average is from 133 individual records in the years 1914 to 1917. Much difference in the time required was found in different years. Longer time was required in the exceptionally cool summer than in 1914 and 1916 when it was very hot.

In both sexes the length of the pupal stage in the summer was essentially the same, as indicated in table VII.

TABLE VII—LENGTH OF PUPAE STAGE; COMPARISON OF RECORDS FOR THREE YEARS

Days as Pupae	Males			Females			Total
	1914	1915	1916	1914	1915	1916	
3	1	....	1	....	....	....	2
4	1	....	1	....	....	2	4
5	....	....	13	....	....	11	24
6	....	....	9	2	....	15	26
7	6	1	2	2	....	5	16
8	5	1	1	2	....	....	9
9	5	2	....	2	....	....	9
10	1	1	....	1	....	....	3
11	1	....	....	....	....	....	1
Average	7.7	8.6	5.4	7.7	....	5.7	....

THE MOTH

Altogether 291 moths were reared in the insectary. The detailed record of the dates they emerged is given in table VIII.

Dr. C. H. Fernald wrote a careful description of the moth, which is copied from the 13th Report of the Illinois State Entomologist.

Imago.—"Expanse of wings, 10-13 mm. Head and thorax, light reddish brown to dull ashy brown; palpi, fuscous on the outside, darker towards the apex, lighter at the base and within; last joint nearly concealed by the long hairs of the second. Antennae dark fuscous, paler beneath. Fore wings with a large, semi-ovate spot of the same brown color as the thorax, resting on the basal half to the hinder margin (inner margin of some authors), and extending two-thirds of the way across to the costa, where it is not always clearly limited

from the costal third of the wing, which is white, tinted with brownish or ochery and marked with a series of minute brown costal streaks with more or less sprinkles of the same color. The outer edge of the semi-ovate spot varies somewhat in form as in other species of this genus. The ground color of the basal half of the costa, changing more or less to a silvery gray in its course, extends across the wing beyond the semi-ovate spot, as a narrow, oblique band, to the hinder margin, where it expands outward and upward, covering a large area on the anal angle and including an oblique brown spot before the angle. The part of the wing above this is concolorous with the semi-ovate spot and marked on the outer half of the costs with four pairs of oblique white streaks, the inner one of which extends to the outer margin a little below the middle. Some specimens show one or two horizontal black streaks near the middle of the outer part of the wing. Fringes sordid white or tinged with ochery, brown at the apex and cut immediately below by two white streaks with brown between. Hind wings and abdomen above, pale fuscous, paler beneath. Underside of the fore wings, fuscous and showing the costal marks of the upper side.

Described from 22 examples; 2 from Orono, Maine, 4 from Pennsylvania, 8 from Missouri, 1 from California, 2 from England, and 5 from Germany." (Fernald)

TABLE VIII—EMERGENCE OF MOTHS IN INSECTARY

April,	1914:	15-1; 16-2; 17-7; 18-3 19-1; 21-8; 22-6; 23-5; 24-1; 25-3; 26-2; 27-3; 28-5; 29-3; 30-1.
	1915:	20-1; 21-3; 24-14; 27-2.
	1916:	19-1.
	1917:	27-2.
May,	1914:	1-1; 2-4; 3-2; 4-3; 5-1; 7-1.
June	1914:	4-1; 5-2; 10-1; 14-1; 15-1; 18-3; 19-4; 20-2; 23-2; 24-3; 25-1; 29-2.
	1915:	18-1 (1910); 22-1 1911); 27-1; 28-3; 29-2.
	1917:	23-3; 24-3; 25-1; 27-4; 28-9; 29-2.
July,	1914:	1-1; 2-3; 3-1; 29-1; 30-1; 31-1.
	1915:	2-1; 7-2; 8-2; 12-1; 13-1; 15-1.
	1916:	16-1; 20-1; 26-1; 28-4; 30-2; 31-1.
	1917:	2-1; 3-19; 5-1; 7-2; 8-3; 10-2; 11-5.
Aug.	1914:	1-2; 3-4; 4-3; 5-3; 6-1; 7-3; 8-2.
	1915:	26-2.
	1916:	1-11; 2-2; 3-4; 4-3; 5-3; 6-3; 7-7; 8-4; 9-4; 10-1; 11-3; 12-1; 13-1; 16-1; 17-1; 24-1; 26-1; 27-1; 29-3; 31-3.
	1917:	1-1; 5-2; 6-1; 8-1.
Sept.	1914:	7-1; 9-1; 10-1.
	1915:	3-1.
	1916:	1-1; 2-1; 3-1; 7-1; 8-1.
	1917:	8-1; 29-1.

When the insect is abundant moths are not difficult to find in an infested field, if one looks during the proper season. They are very alert and dive underneath foliage so quickly close watching is required to see where they go. The eggs are deposited at night.

LENGTH OF LIFE OF THE MOTHS.

Some data on the length of life of the adult moths were secured in insectary cages, where individual pairs were confined for egg records. As a rule a little water sweetened with sugar

LENGTH OF LIFE OF INDIVIDUAL MOTHS.

TABLE IX—FEMALE.

1914	1915	1916
8 days	8 days	6 days
18	4	9
24	7	12
28	11	16
18	....	10
7	....	8
8	....	7
5	....	....
9	....	....
9	....	....
6	....	....
16	....	....

TABLE X—MALE.

1914	1915	1916
16 days	7 days	5 days
18	7	4
21	7	11
23	11	10
8	....	10
10	....	3
6	....	8
6	....	....
3	....	....

was placed in these cages for food. In 1916 honey was substituted for sugar.

Twenty-four female moths lived on an average of 10.2 days, with a range of from 3 to 28 days. The individual records are given in table IX.

Nineteen male moths lived on an average of 10.1 days, with a range of from 3 to 23 days. It was thought that the male died more quickly in the cages than the females, but the average is too slight to consider of any imoprtance. The individual records are given in table X.

In compiling these data only accurate records were used. In some cases moths were noted in the insectary experiments as having escaped. All these records were thrown out, since the time of death of the insect was uncertain.

NATURAL ENEMIES

At no time during the period during which this insect was studied at Ames did natural enemies appear in abundance. Rarely a Braconid cocoon was found on an infested leaf. While several parasites were reared, only one has been determined.

This particular species was an external parasite, *Iseropus alboricta* Cresson (Gahan determination) reared in the fall of 1914. When found October 22 at Ames this larva was 3.5 mm. long, and attached to a mature strawberry leaf-roller. The parasite grew rapidly and October 26 spun a white, loose, silken cocoon 10x4 mm. Sometime in November the adult emerged, but the exact date was not determined.

C. M. Weed (1880) reported that two species of Hymenopterous parasites had been observed in Illino's. These were *Cremastus cookii* Weed and *Glypta phaxopteridis* Weed.